Digital Lensmeter for Unknown Prescription Lens

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Background Information

1.3 billion people around the world suffer from some form of visual impairment.

Main causes of visual impairment:

- Refractive Errors (most common)
- Cataracts
- Glaucoma

Visual impairments stem from:

- Congenital Factors
- Environmental Factors

Congenital Eye Forms

Emmetropic Eyes

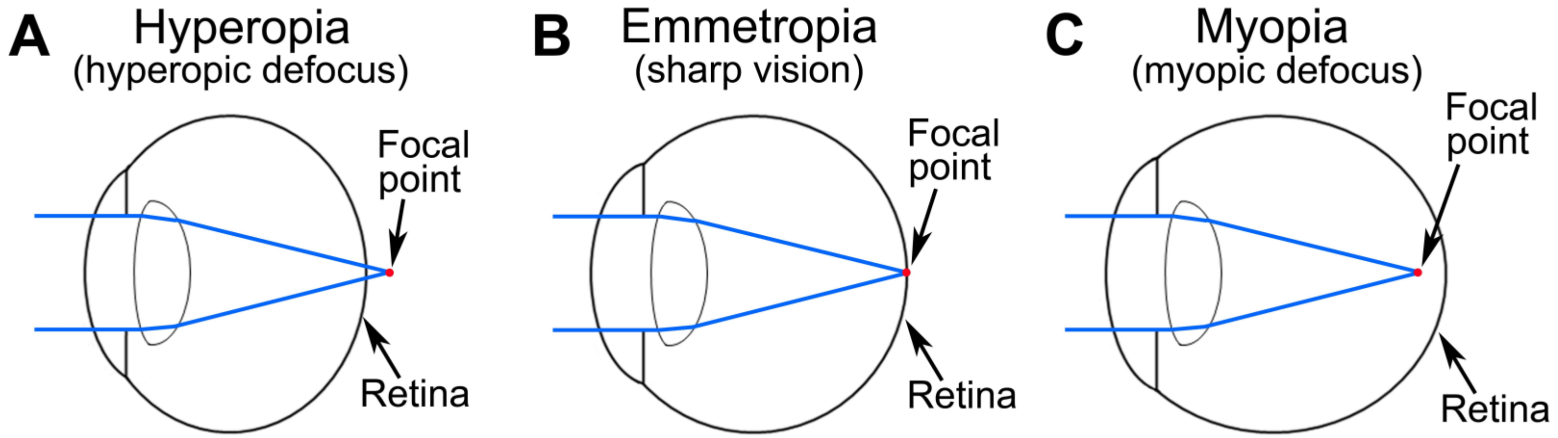
Eyes that do not require any vision correction.

Hyperopic Eyes

Eyes in which visual images come to focus behind the retina of the eye.

Myopic Eyes

Eyes in which visual images come to focus in front of the retina of the eye.



Refractive Errors

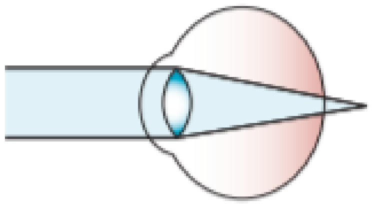
There are two forms of refractive errors:

Myopia (Short-Sightedness)
- aka Nearsightedness
- Clear vision when looking at objects up close, but at a distant objects are blurred
- Light focused in front of the retina

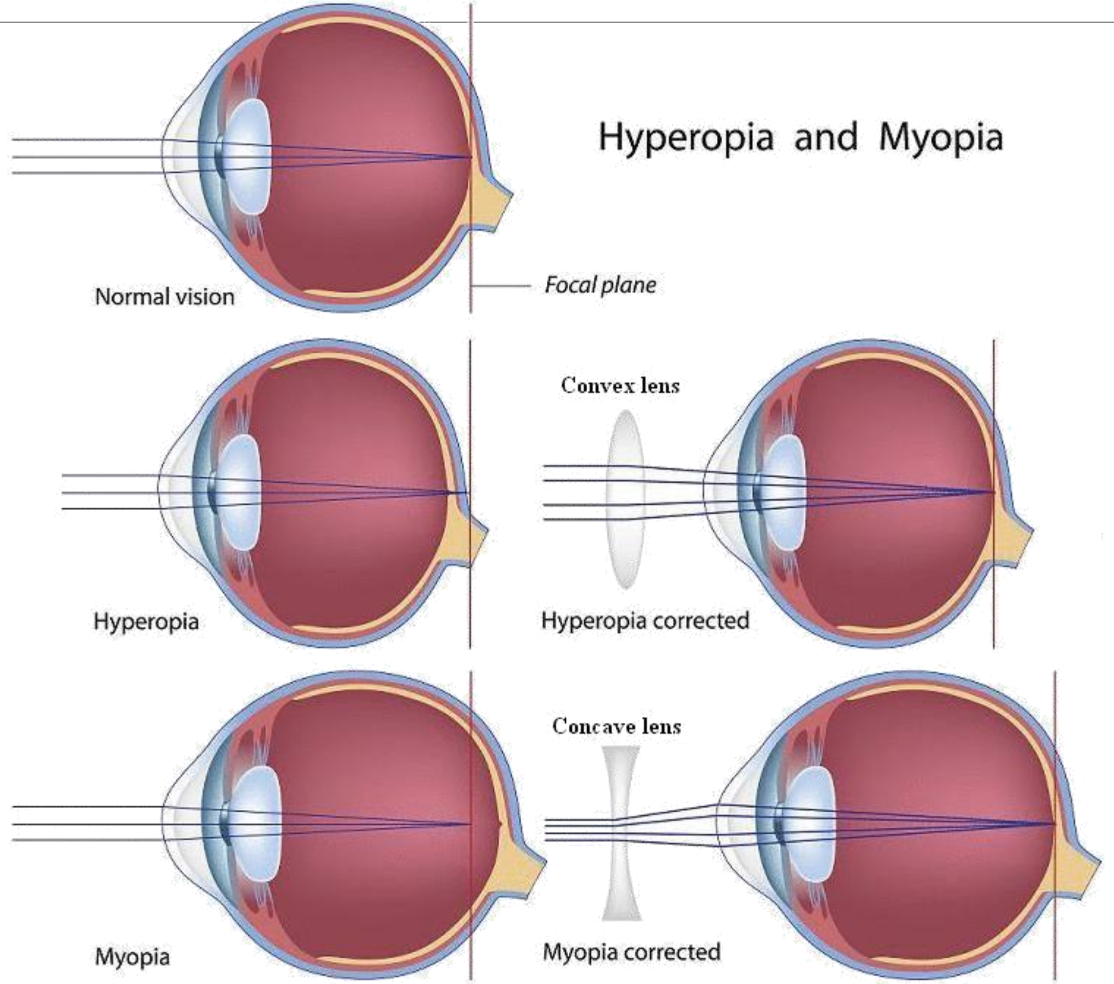
Hyperopia (Long-Sightedness)
- aka Farsightedness
- Clear vision when looking at objects at a distance, but closer objects are blurred
- Light focused behind the retina

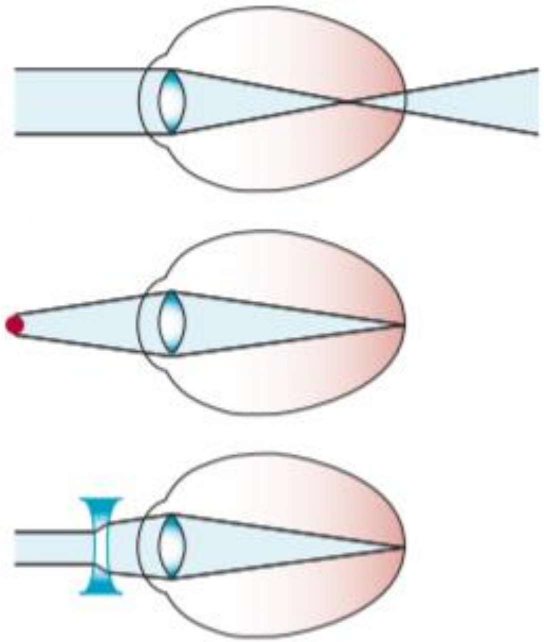
These can both be corrected through the use of glasses that refract parallel light coming into the eye.

Hyperopia vs. Myopia



Exaggerated Hyperopia





Exaggerated Myopia

Optics Laws

Lens Law

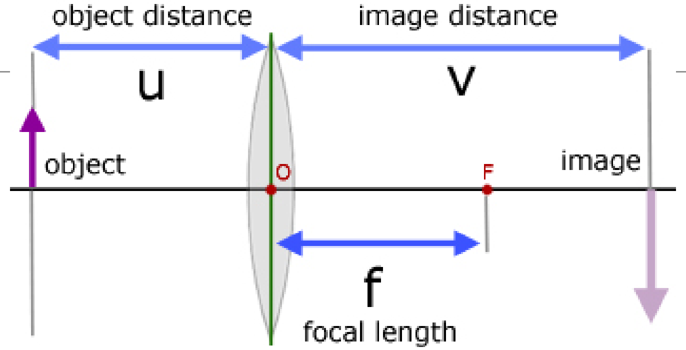
$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

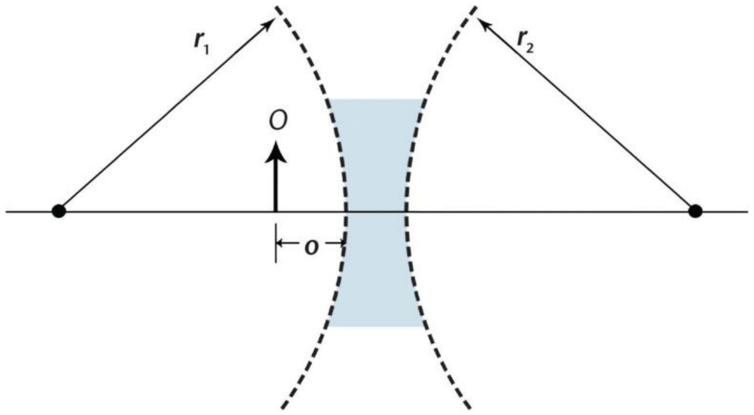
Lensmaker's Equation

$$\frac{1}{f} = (n-1)(\frac{1}{r_1} - \frac{1}{r_2})$$

Power

$$P = \frac{1}{f}$$





n = index of refraction
r1 = 1st curvature
r2 = 2nd curvature

Units:
P = D (diopters)
f = meters

Diopter

A magnifying power of a lens or lens system is a diopter.

It can be quantified by the equation:

$$P = \frac{1}{f}$$

Units:
P = D (diopters)
f = meters

Doctors prescribe glasses in 0.25 D intervals

The human eye can detect 0.15 D intervals, but this is not as efficiently rounded as 0.25 D

Examples:

OD: -4.25 → 4.25 Diopters of nearsightedness in the right eye

OS: +3.25 → 3.25 Diopters of farsightedness in the left eye

Prescriptions

$$Prescription: S \pm C \times Axis$$

S – The “spherical” portion of the prescription that depicts the degree of nearsightedness or farsightedness.

C – The “cylinder” portion or astigmatism (can be negative or positive)

This is a result of the cornea shaped as a football rather than a sphere

Axis – The orientation of the astigmatism

Difference in curvature occurring of the cornea

Examples:

-2.00 -1.50x180 → 2 diopters of nearsightedness with 1.5 diopters of astigmatism and axis of 180 degrees

+3.50 SPH → 3.5 diopters of farsightedness (spherical eye)

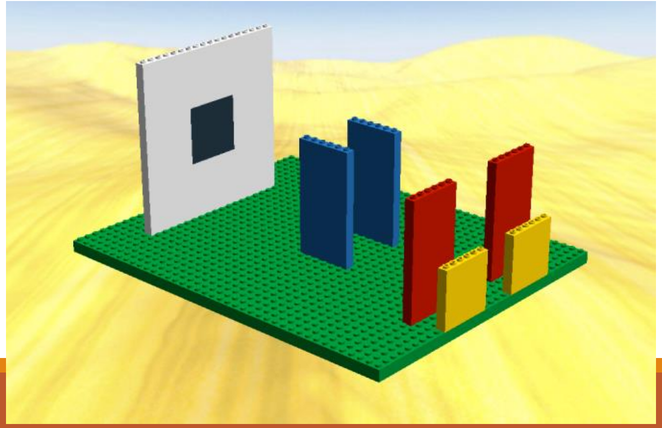
Lensmeter

An instrument that is used by opticians to determine the correct prescription in a pair of glasses.

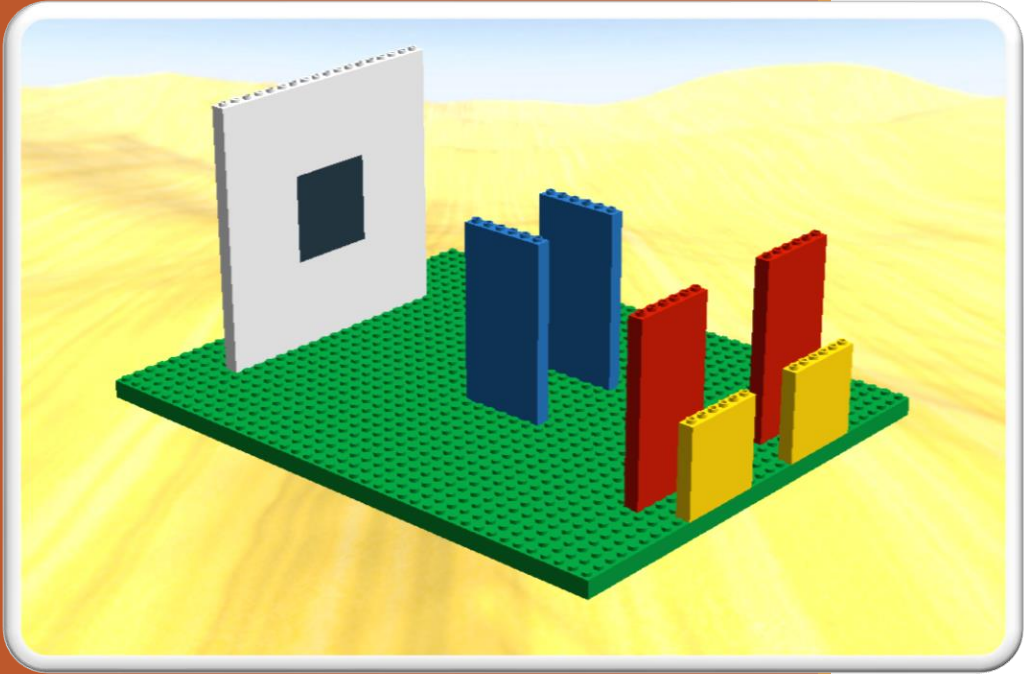
$$Prescription: S \ \pm C \times Axis$$

Objective

To demonstrate a prototype of a lensmeter using MatLab and every day items to find the prescription strength of a pair of glasses.



Methods



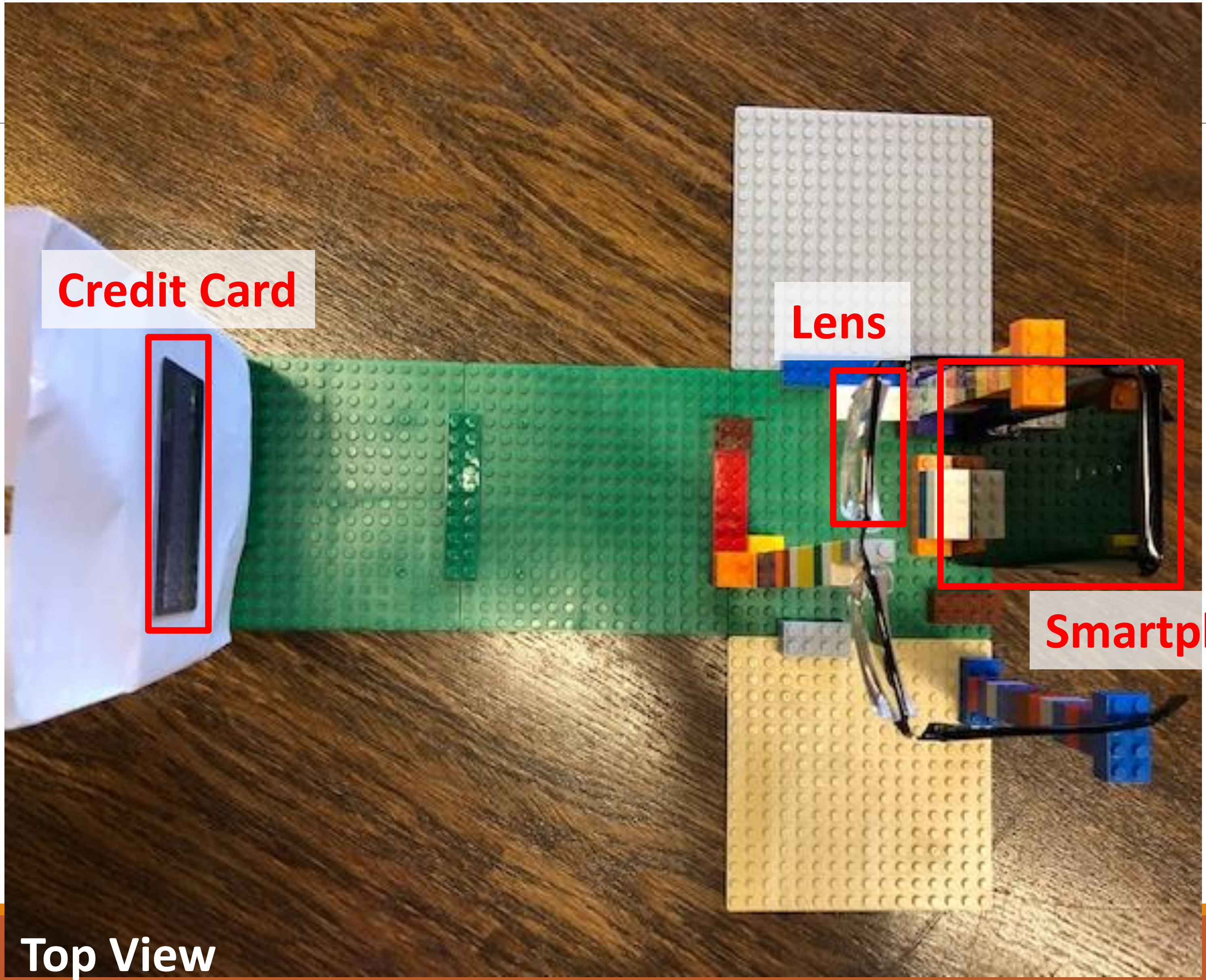
Fixed Parameters - Distance between Lens, Camera, and Card

Create a **statistical database** for the ratios of the images with respect to a converging or diverging lens to one without one

Find a fitting function for the graph of the ratio of **magnification vs known prescription power (D)**

Use the best fit equation to **determine the power of an unknown** lens

Setup



Flowchart

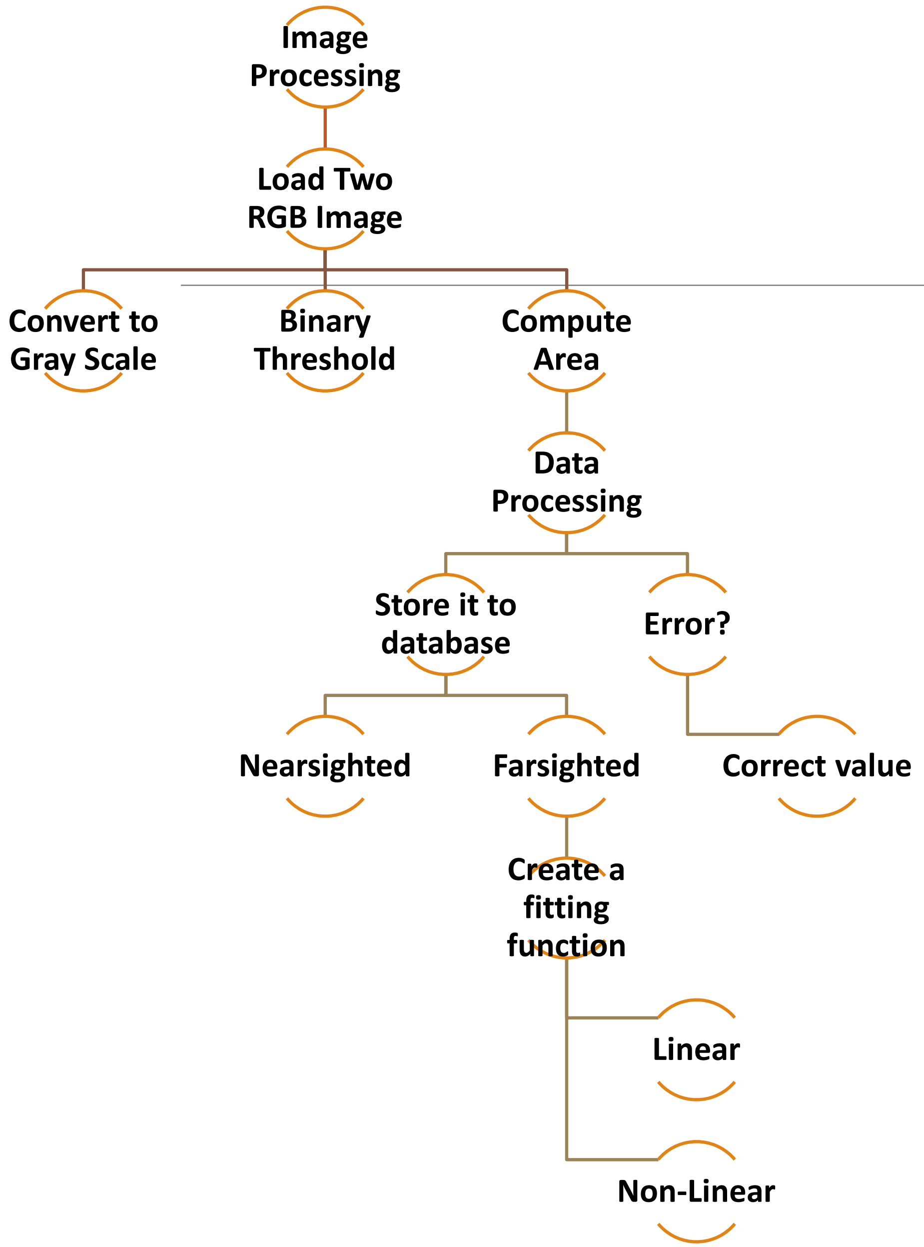
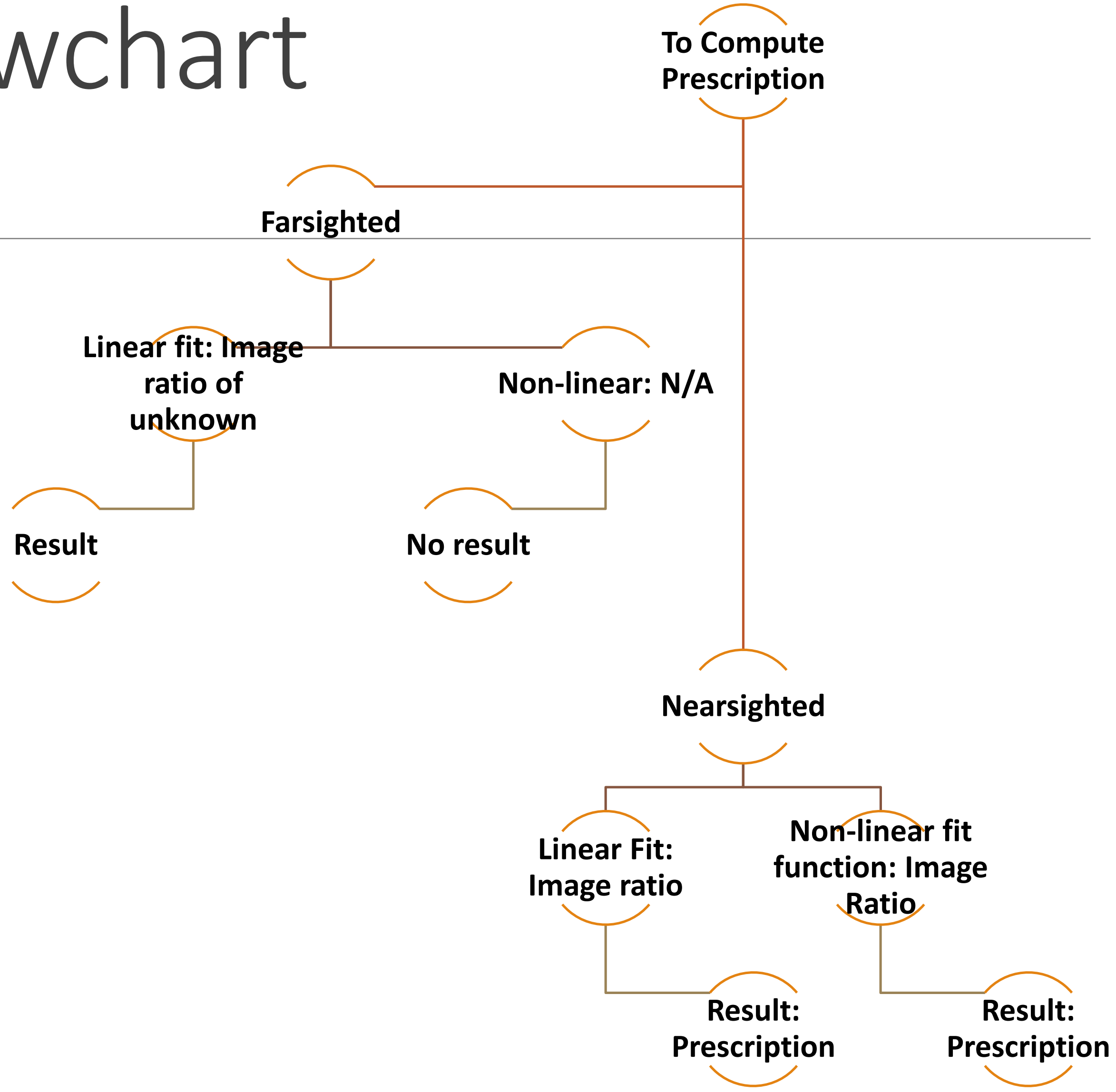


Image Processing
Load Two RGB Image
Convert to Gray Scale
Binary Threshold
Compute Area
Data Processing
Store it to database
Error?
Nearsighted
Farsighted
Correct value
Create a fitting function
Linear
Non-Linear



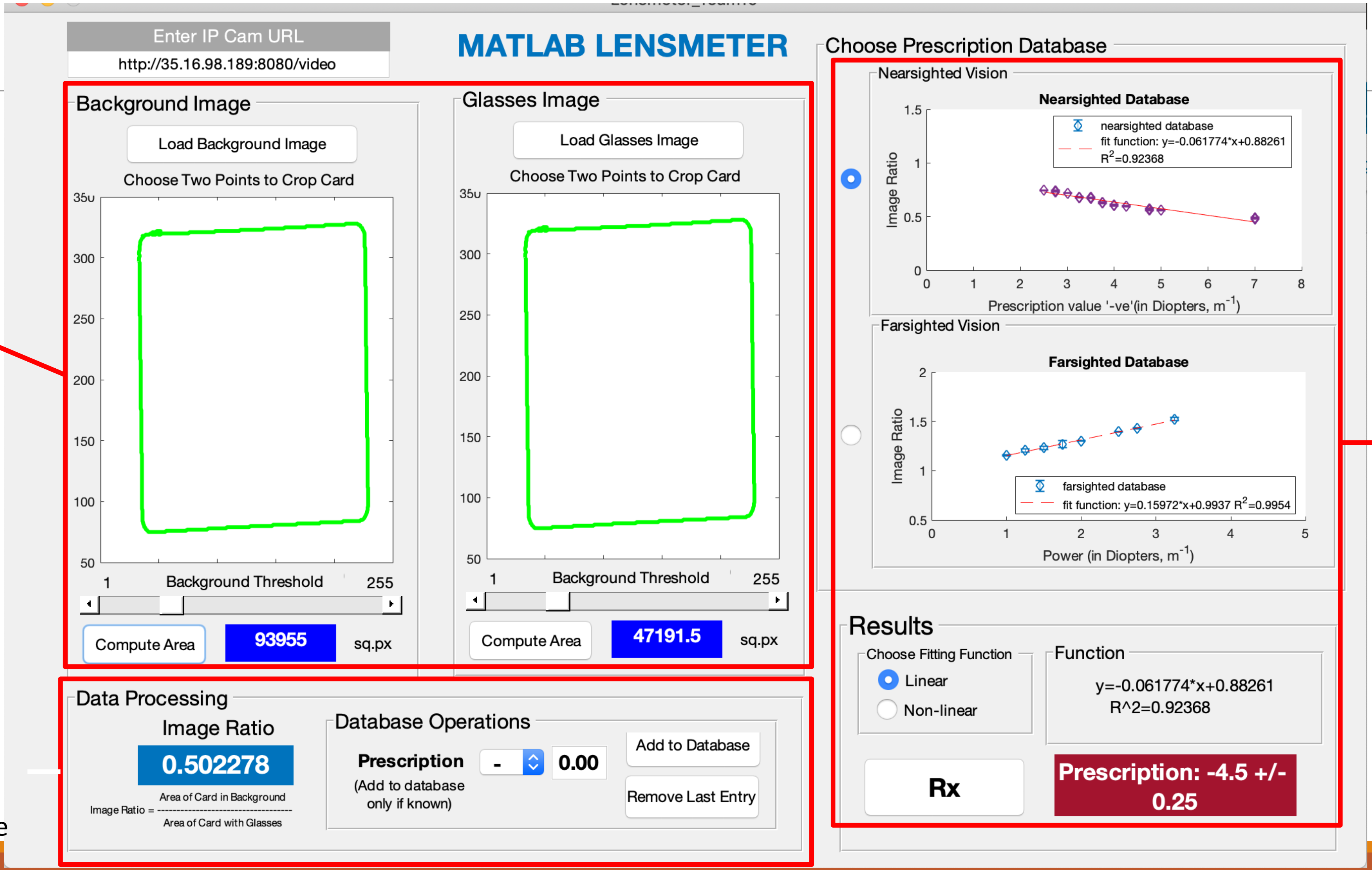
To Compute Prescription
Farsighted
Linear fit: Image ratio of unknown
Non-linear: N/A
Result
No result
Nearsighted
Linear Fit: Image ratio
Non-linear fit function: Image Ratio
Result: Prescription
Result: Prescription

GUI

III. Output
a. Calibration Equation
b. Calibration Curve
c. Estimated Prescription
d. Rounded Prescription

I. Image Processing
a. Acquire
b. RGB to Binary
c. Find area with glasses and without
d. Find the Ratio

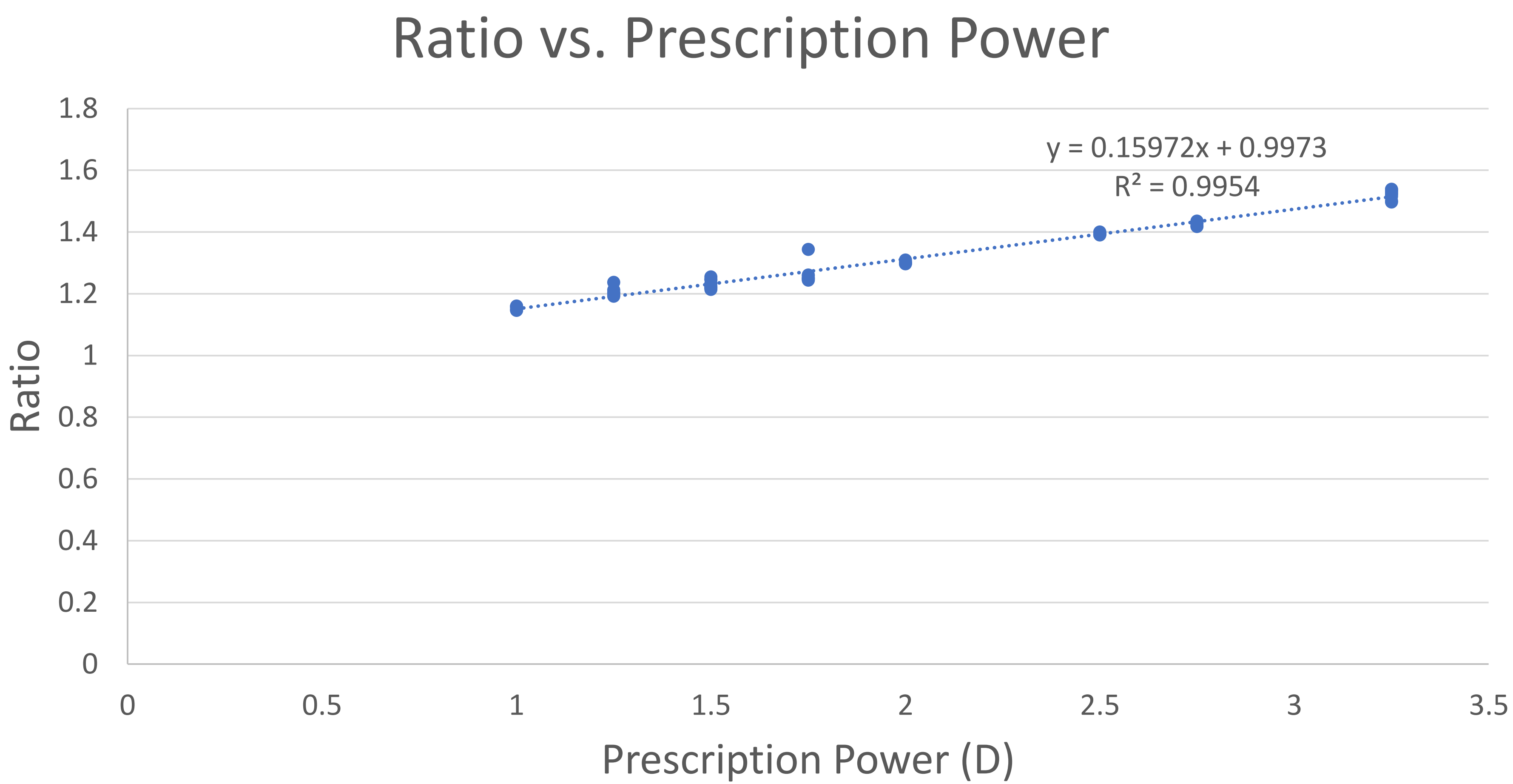
II. Data Processing
a. Acquire
b. Enter or Erase in file
c. Create a calibration curve



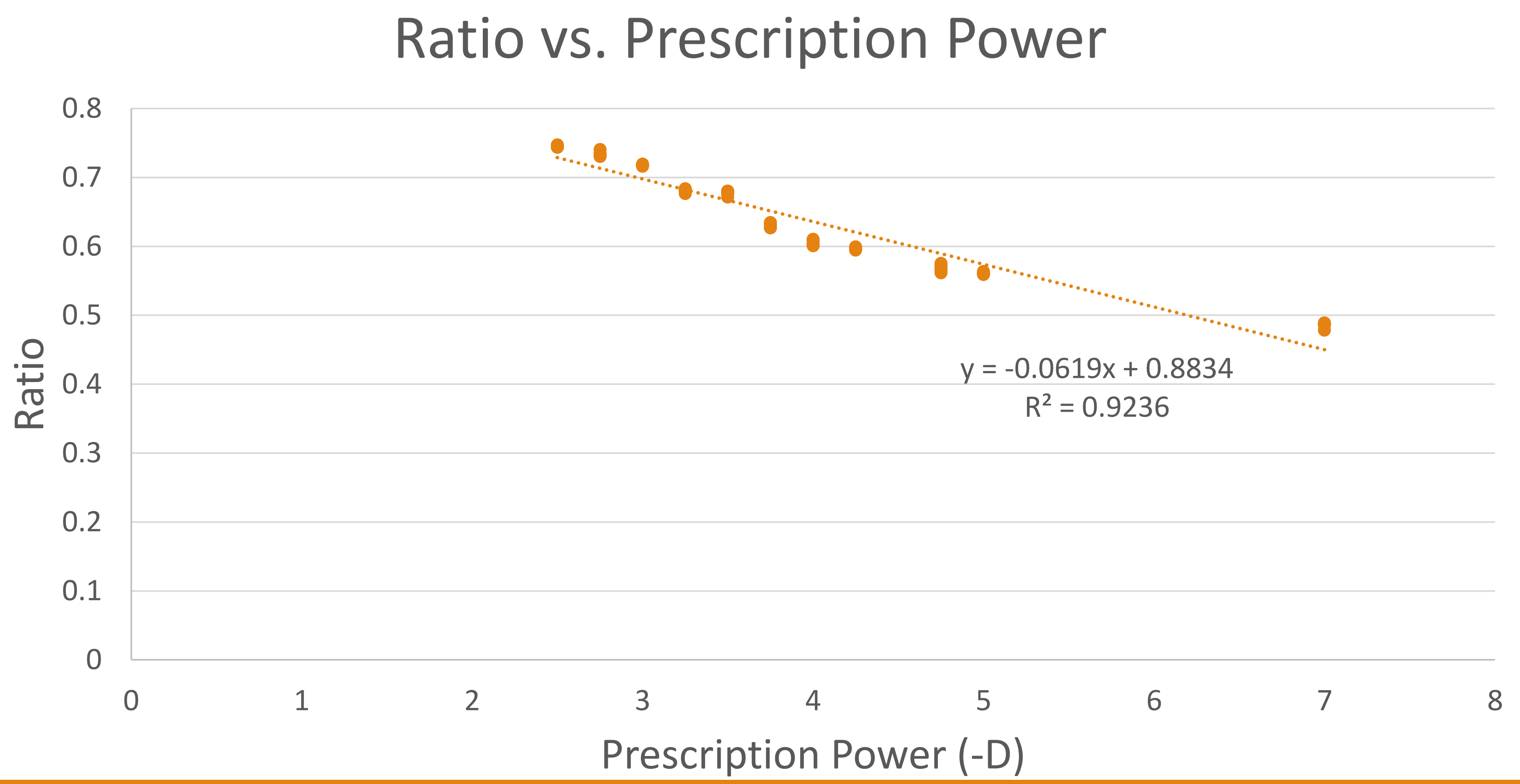
Using the GUI to find Unknown Prescription Power

UTILIZING NEARSIGHTED AND FARSIGHTED LENSES

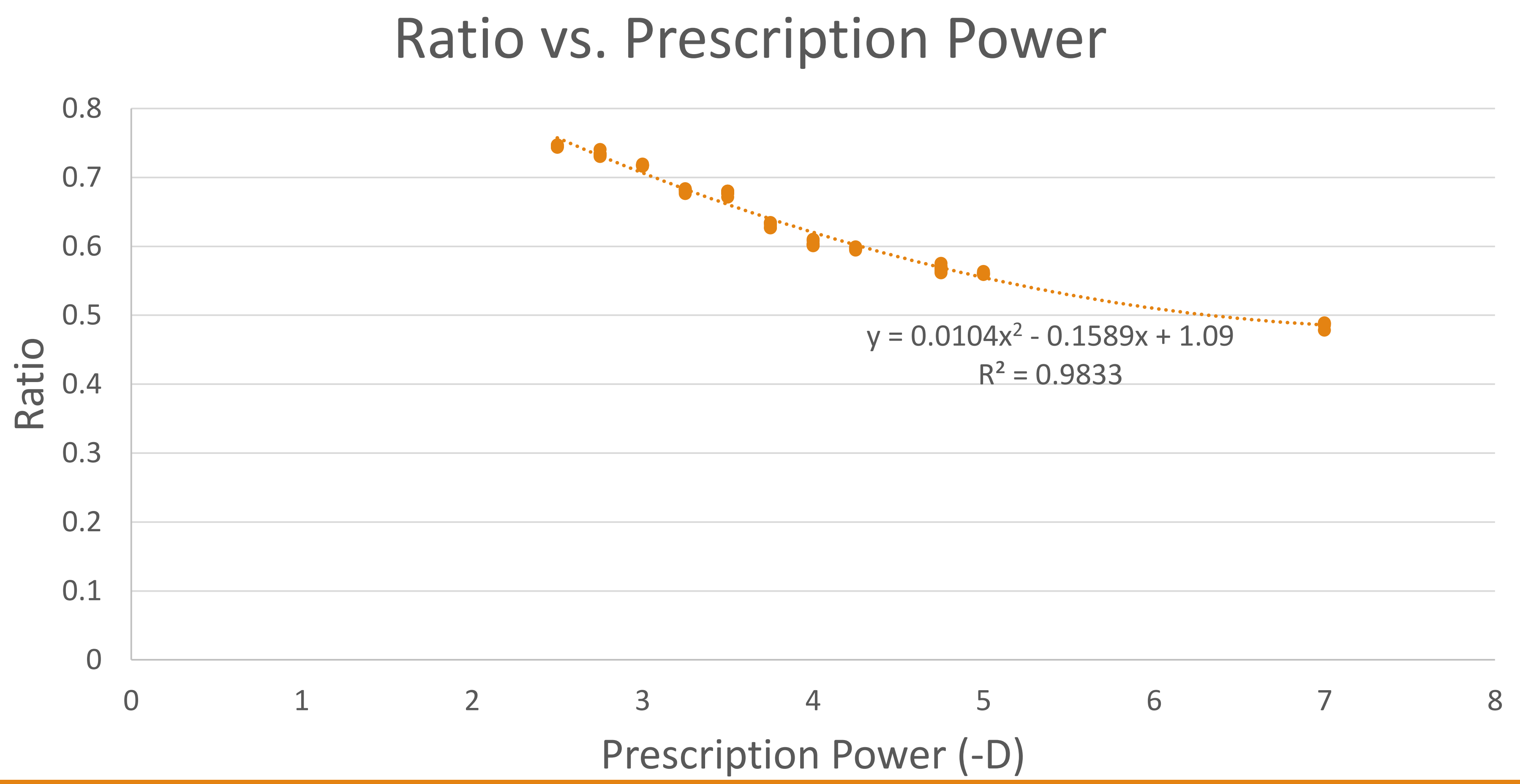
Best Fit: Linear (Farsighted Lens)



Best Fit: Linear (Nearsighted Lens)



Best Fit: Polynomial (Nearsighted Lens)



Linearization

$$f(x) = 0.0104\mathrm{x}^2 - 0.1589\mathrm{x} + 1.09 \text{ at } x_0 = 4.25$$

$$L(x) = f(x_0) + f'(x_0)(x - x_0)$$

$$f(x_0) = \frac{24101}{40000} \approx 0.602525$$

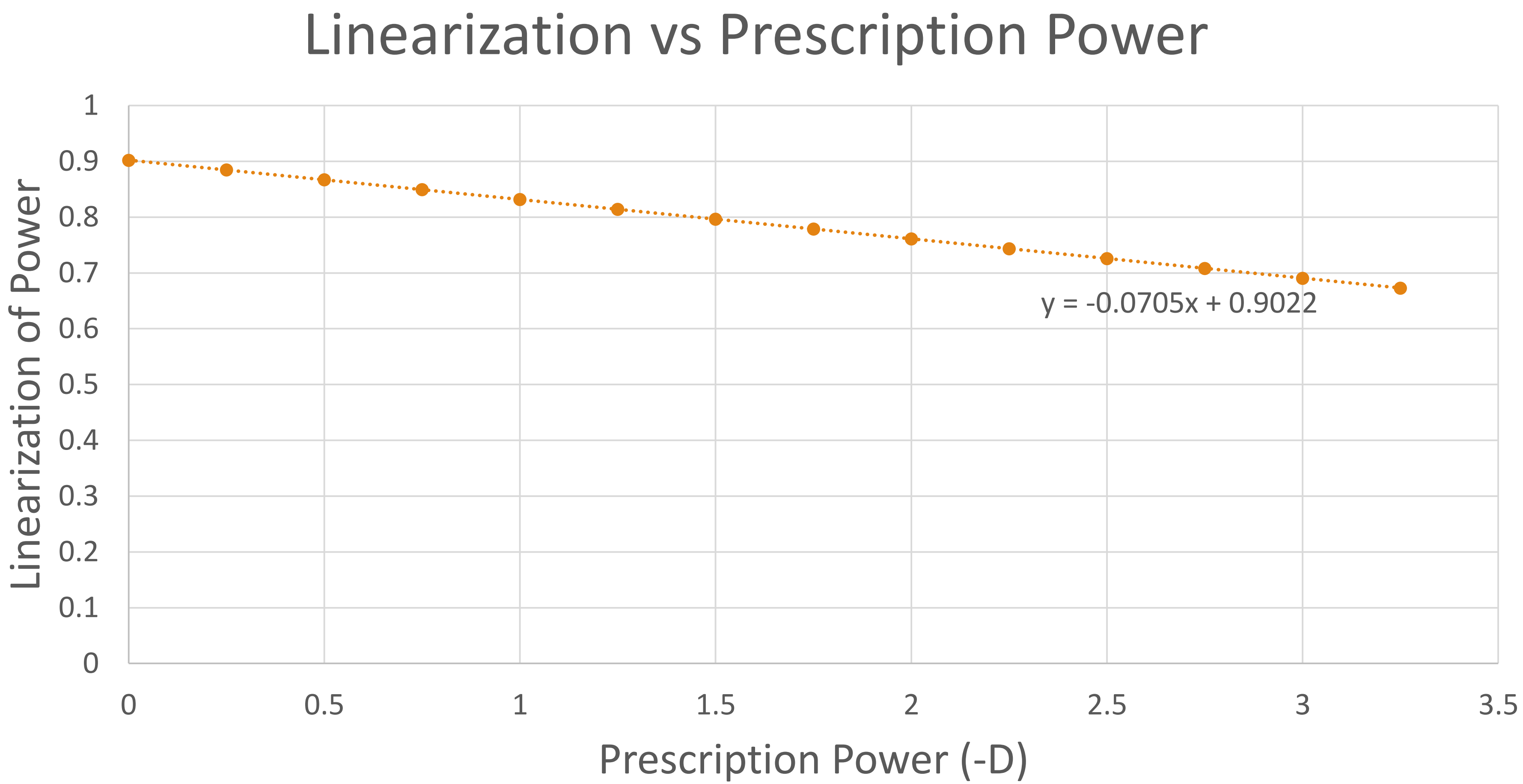
$$f'(x) = \frac{13x}{625} - \frac{1589}{10000}$$

$$f'(x_0) = \frac{13(4.25)}{625} - \frac{1589}{10000} \approx -0.0705$$

$$L(x) = \frac{24101}{40000} - \frac{141}{2000}(x - 4.25)$$

$$L(x) = -0.0705x + 0.90215$$

Graph of Linearization



Possible Errors and Limitations

Hyperopia was tested on OTC lenses only: +1.00 to +3.25

- Hyperopia lenses vary up to +5 (prescription strength)

Myopia was tested on prescriptions of -2.5 to -7

Tested only with Andriod – Free application

Limited to only spherical powers

- Prescriptions with astigmatisms can disrupt ration calculations due to cylindrical and axis values.

Cannot read anisometropia glasses (dual nearsighted or farsighted)

Unknown image distance and focal length (known object distance)

Possible error: image analysis

- When taking the surface area
- Shadow of credit card (can add area to ratios)

Conclusion

Myopia and Hyperopia are prevalent in many parts of the world and affects around 15% of the population.

The GUI and setup provided, is a very simple way to find prescriptions of lenses.

- The end user is able to find a prescription in 4 clicks

Astigmatisms are a crucial error in the model as they skew results since rotation around an axis throws off readings.

- In order to compensate for this error, a static error of ±0.25 was instituted

Further trials and prescriptions will be required to add cylindrical and axial values that are in every prescription to the model.

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